Air filters and air cleaners: Rostrum by the American Academy of Allergy, Asthma & Immunology Indoor Allergen Committee

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The allergist is generally recognized as possessing the greatest expertise in relating airborne contaminants to respiratory health, both atopic and nonatopic. Consequently, allergists are most often asked for their professional opinions regarding the appropriate use of air-cleaning equipment. This rostrum serves as a resource for the allergist and other health care professionals seeking a better understanding of air filtration. (J Allergy Clin Immunol 2010;125:32-8.)

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Abbreviations used

AHAM:	Association of Home Appliance Manufacturers
ASHRAE:	American Society of Heating, Refrigerating, and Air-Conditioning Engineers
EAC:	Electronic air cleaner
HEPA:	High-efficiency particulate air filter
HVAC:	Heating, ventilation, air-conditioning system
MERV:	Minimum efficiency reporting value
PM:	Particulate matter
WHF:	Whole-house filtration

Home environmental intervention[1] strategies are effective in reducing allergic respiratory disease manifestations. To date, most research has focused on allergens.[2] Clinicians often ignore other airborne particulate matter (PM), which might play a significant role in human respiratory disease. Consequently, air filtration studies focused only on the efficacy of reducing airborne allergens might fail to recognize the health benefits of air filtration.

The study of the effectiveness of avoidance measures is limited by the fact that a single method is not enough. Multiple interventions over a long period of time (at least 1-2 years in duration) might be required to yield meaningful clinical results. Studies using single interventions (eg, well-established single interventions, such as impermeable mattress covers[3]) in short-term trials have often proved ineffective. As a consequence, allergists might underemphasize these measures, especially in the face of the quick effect on disease symptoms offered by pharmacotherapy.[4] Even with effective pharmacologic interventions, disease progression benefits are often lost on discontinuation.[5] Environmental control measures might result in significant reduction of disease symptoms and progression by eliminating or reducing exposures.

CHARACTERISTICS OF AIRBORNE PARTICULATES TO BE FILTERED

Exposure to allergens and PM and our ability to filter them from the air depends largely on their physical properties (ie, aerodynamic diameters and settling rates, such as size and density, as well as their concentrations, aerosolization, airflow, and dilution rates). Analysis of the aerodynamic size of vacuumed dust samples[6] revealed that dog allergens were narrowly distributed from 5 to 7 μm in diameter, but endotoxin and cat allergens were distributed over a wide range of 5 to 30 μm. Mite allergens were found in relatively large particulates with a mean aerodynamic diameter of 28 μm, but smaller fragments can be found. Larger allergen sources (ie, mite, cockroach, mold, and pollen) appear primarily to reside in settled dust and become airborne to varying degrees when disturbed. Smaller allergens (ie, cat,

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TABLE I. ASHRAE standard testing method 52.2-2007 MERV table

Standard 52.2 MERV	Composite average PSE (%) in size range: Range 1 (0.30-1.0 μm)	Range 2 (1.0-3.0 μm)	Range 3 (3.0-10.0 μm)	Average arrestance (%) by standard 52.1-1992 method	Minimum final resistance: Pa	Inches of water
1	NA	NA	E3 < 20	Aavg < 65	75	0.30
2	NA	NA	E3 < 20	65 ≤ Aavg < 70	75	0.30
3	NA	NA	E3 < 20	70 ≤ Aavg < 75	75	0.30
4	NA	NA	E3 < 20	75 ≤ Aavg	75	0.30
5	NA	NA	20 ≤ E3 < 35	NA	150	0.60
6	NA	NA	35 ≤ E3 < 50	NA	150	0.60
7	NA	NA	50 ≤ E3 < 70	NA	150	0.60
8	NA	NA	70 ≤ E3	NA	150	0.60
9	NA	E2 < 50	85 ≤ E3	NA	250	1.00
10	NA	50 ≤ E2 < 65	85 ≤ E3	NA	250	1.00
11	NA	65 ≤ E2 < 80	85 ≤ E3	NA	250	1.00
12	NA	80 ≤ E2	90 ≤ E3	NA	250	1.00
13	E1 < 75	90 ≤ E2	90 ≤ E3	NA	350	1.40
14	75 ≤ E1 < 85	90 ≤ E2	90 ≤ E3	NA	350	1.40
15	85 ≤ E1 < 95	90 ≤ E2	90 ≤ E3	NA	350	1.40
16	95 ≤ E1	95 ≤ E2	95 ≤ E3	NA	350	1.40

Results are grouped into 3 ranges (domains) reflecting average particle size efficiency *(PSE)*. The higher the MERV, the higher the efficiency in filtering fine particles. *Arrestance* is defined as the percentage of total test dust removed measured by weight in grams. Minimum final airflow resistance is measured in Pascals or inches of water.
Aavg, Average arrestance; *E1*, Efficiency range 1; *E2*, Efficiency range 2; *E3*, Efficiency range 3.

dog, and some molds, such as *Penicillium* and *Aspergillus* species) might remain airborne for longer periods. Both inhalable coarse PM (diameter, 10–2.5 μm) and fine PM (diameter, <2.5 μm) penetrate into indoor environments and can be measured in the ambient air of residential dwellings.

TESTING PROCEDURES: HEATING, VENTILATION, AIR-CONDITIONING SYSTEM FILTERS

MERV is an acronym for "minimum efficiency reporting value" and is assigned to filters based on the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) standard testing method, 52.2-2007.[7] The efficiency testing uses a challenge aerosol measured in 12 particle sizes ranging from 0.30 to 10.0 μm. When testing residential filters, the airflow velocity will be about 300 ft/min, approximating the typical airflow velocity of residential heating, ventilation, air-conditioning system (HVAC) systems (typically with a forced air blower fan). Laser particle counters are used to measure the differential particle count across the filter. The results are grouped in 3 domains reflecting the average particle size efficiency in each domain. These correspond to range 1, range 2, and range 3 in Table I. From these, the MERV is determined. Filter ratings for residential and office applications typically range from MERV 1 to MERV 12. The higher the rating, the better, with MERV 12 having ratings of at least 80% efficiency for particles in the 1.0- to 3.0-μm size range and 90% or better in the 3.0- to 10.0-μm range. Although MERV is the commonly accepted way to domestically assess performance of air filtration products, not all manufacturers or marketers of filtration products subscribe to the "1-number" summation that MERV dictates. The underlying data used to assimilate MERV are the efficiency versus particle size data product. Many filtration product research and development efforts use these base data for product decision making and leave the "1-number" judgment of MERV as a marketing tool.

In addition to efficiency, filter attributes also include a reasonable holding capacity and adequate airflow for ventilation. The holding capacity should be adequate do that the filter does not become fully loaded for a reasonable length of time for maintenance purposes (often 3 months). Another factor to consider is that media filters become more efficient as they load, whereas electronic cleaning devices that need to be washed or wiped rapidly lose efficiency as the plates that generate the electrostatic charge become coated with particles.

There are no mandated formal certifications of performance in the United States for testing to the standards mentioned here. Manufacturers of unit filtration products have at least 3 options to prove performance claims under third-party testing, all using the ASHRAE 52.2-2007 or portions of it as the protocol:

1. Independent testing laboratories that are capable of conducting the test method.
2. The National Air Filtration Association Product Certification program provides an organized protocol that confirms performance to the ASHRAE standard.
3. The US Environmental Protection Agency maintains an Environmental Technology Verification program in which product performance is verified to meet the manufacturers' claims.

TESTING PROCEDURES: PORTABLE ROOM AIR CLEANERS

Portable room air cleaners and devices are rated in accordance with the Association of Home Appliance Manufacturers (AHAM) standard[8] Test Method for Performance of Portable Household Electric Room Air Cleaners. Device performance is determined by placing the test device into a controlled, sealed test chamber of a prescribed volume into which standardized aerosolized smoke, dust, and pollen are introduced. The standardized aerosols and size ranges are as follows:

1. cigarette smoke in the 0.09- to 1.0-μm particle size range;
2. International Organization for Standardization (a nonprofit network of the national standards institutes of 161

countries; http://www.iso.org/iso/about.html) fine calibrated test dust in the 0.5- to 3.0-μm particle size range; and
3. mulberry pollen in the 5- to 11-μm particle size range.

The decay of the presence of these aerosols is then quantified into a clean air delivery rate for each of the aerosols. The higher the number, the faster the device cleans the air to normal background levels. Manufacturers of portable room air cleaners have the option of using third-party testing laboratories capable of conducting the AHAM AC-1-2006 standard independently. AHAM also provides a further enhancement of this by administering a formal certification approval process in which the manufacturer is given approval to label the product with the clean-air delivery rate numbers.

There are similarities in the 2 standards that are important to note:

1. Both methods are voluntary; manufacturers are not required to conduct these tests.
2. The American National Standards Institute, A 501(c)3 private, not-for-profit organization that promotes and facilitates voluntary consensus standards and conformity assessment systems, affirms both methods.
3. Both methods are used in formal product certification or performance verification programs.
4. Neither method addresses the removal of gases or odors.
5. Neither method addresses the removal of microbiologic components.
6. Neither method addresses the generation or removal of ozone.

AIR-CLEANING OPTIONS IN RESIDENTIAL BUILDINGS

Air-cleaning products and devices for residential buildings can best be classified into 2 road categories:

1. whole-house filtration (WHF; ie, filters or cleaners that are installed on the central HVAC system) and
2. free-standing portable room air cleaners.

WHF (HVAC FURNACE FILTERS)

The primary goals of air filtration placed in HVAC units in the home environment are as follows:

1. maintenance of a clean environment for the comfort of the occupants;
2. protection of the decor of occupied spaces by removing the staining portion of airborne dust;
3. reduction of fire hazards by removing lint and other combustible materials from forced air ductwork;
4. protection of the mechanical parts of the HVAC system;
5. reduction of particulates potentially harmful to the occupants; and
6. removal of odors.

WHF is used in central HVAC systems in which large portions of the interior air are transported to the equipment to be heated, cooled, and cleaned before being recirculated back into the occupied space. Some systems provide a means of introducing fresh outside air as well. Disposables filters are available in a wide range of performance levels and costs. Typical forms range from the inexpensive fiberglass flat pads to pleated filters with a large media area. A worldwide study of housing and asthma[9] identified ducted heating and air conditioning as 2 of the 5 housing characteristics associated with asthma and bronchial responsiveness. Several other characteristics that allergists would normally consider important risk factors (eg, wall-to-wall carpets) were not found to be significant. According to the 2007 American Housing Survey sponsored by the US Department of Housing and Urban Development, there are 92.9 million US housing units (75%) with forced air ducted heating systems requiring air filters.[10] Ninety-five percent of these use 1-in panel filters. The average annual expenditure per residence for furnace filters is reported by the census data to be $2.60 per year (about a nickel per week). This might indicate either the lack of attention to regular changing of the filters, the purchasing of inexpensive and poorly efficient filters, or both. In addition, it is common that the channels for the filters and the ductwork are made of sheet metal. Often, the filter might fit poorly in the track, allowing significant air leakage around the filter or in the ductwork itself.

The concept of WHF with either high-efficiency, high-capacity media furnace filters or electronic air cleaners (EACs) with properly sealed ductwork offers the potential of not only keeping the air-handling equipment clean of small particulates, allergens, and fungal spores but also affecting indoor air quality and health. In the field of building science and health, contamination of ducted systems has been shown to be reduced by improved whole-house air filtration. A recent standard[11] published by ASHRAE established that "mechanical systems that supply air to occupiable space through ductwork exceeding 10 ft (3 m) in length should have a filter with a designated minimum efficiency of MERV 6, or better, when tested in accordance with standard ASHRAE Standard 52.2."

HVAC furnace filters can be divided into the following groups:

1. panel filters;
2. high-efficiency particulate air (HEPA) filters;
3. washable/reuseable filters;
4. EACs; and
5. hybrid combinations of the prior types.

PANEL FILTERS

Inexpensive panel filters made of flat mats of either fiberglass or synthetic fibers have been used in furnace filters for more than 75 years. They offer no benefit to small particulate filtration and might worsen the problem by capturing and then dumping particulates downstream. They generally have no or a very low MERV rating of 1 to 2. Their low cost makes them popular in apartments or low-income housing.

Multipleat extended surface filters are the most common type of panel furnace higher-efficiency filters. They can be made of various fabric media, such as fiberglass, cotton, and synthetic materials. Concerns related to pressure decreases across the filter are alleviated by pleating; this allows for more media loading but does not increase efficiency, which is a function of characteristics of the media. The most effective are usually of nonwoven materials, such as polyolefin, and can reach a MERV of 11 or 12 in 1-in pleated panel models. The American Lung Association Health House recommends MERV 11 or higher.[12] Filter change intervals are recommended every 3 months for normal residential use, with annual

replacement costs of approximately $40 to $80. Custom installed 2- to 5-in filters offer higher capacity but are more expensive.

Washable panel filters are usually made of either a metal or woven nylon filament. They depend on the natural electrostatic charge of the filter materials to attract particulates through interception of the particle. As the filter loads and the charged materials are coated, the efficiency of the filter might decrease dramatically. Another consideration is that inadequate cleaning of the filter by washing might leave residual damp dirt that can provide a substrate for mold or bacterial growth.

HEPA HVAC FILTERS

During the World War II effort, the US military developed filtration products to deal with anticipated airborne radioactive contaminants. The acronym HEPA was used to identify these high-efficiency products, and the term has since developed into a generic descriptor for highly efficient filters. The Institute of Environmental Science and Technology (document IEST-RP–CC0341.1, "HEPA and ULPA filter leak tests") best defines HEPA products as filters having "… minimum particle collection efficiency of 99.97% on 0.3 μm particles of specified aerosol." Note that this might mean that the minimum particle efficiency is better at particle sizes greater than and less than that size, but the intent with the term HEPA was to deal with particulates larger than 0.3 μm. Forms of inappropriate misuse of the term include "HEPA-type" or "HEPA-like" and can falsely imply that these products meet the performance requirements.

HEPA filters for HVAC systems require bypass systems whereby up to 80% of the air intake does not pass through the filter because of high airflow resistance. Furnace HEPAs are highly efficient in closed systems, such as clean rooms. Their effectiveness in open residential settings does not reach that level, and because of the expense differential, they are not generally cost-effective.

POWERED ELECTRONIC FILTERS (EACs)

Powered electronic filters are commonly called EACs. These devices are small electrostatic precipitators in which the entering dust and air are ionized in a high-voltage electric field. Particulates are then precipitated onto collecting surfaces downstream in the device. HVAC installers often recommend EACs or hybrids with a media or washable prefilter and a second-stage EAC. When clean, the electronic plates are highly efficient with low airflow resistance, and thus it is less likely for the homeowner to notice decreased airflow if infrequently serviced. However, they tend to quickly lose efficiency as the plates load and become covered with dust. Most manufacturers recommend monthly cleaning regimens that often are not followed. This can easily compromise performance, negating the presumed superior performance of a "powered" device. The electronic grids can produce low levels of ozone, but because the cleaners are installed on the central HVAC system away from the living space, this is not usually considered a problem.

COMPOSITE COMPONENT SYSTEMS

Composite component systems are a new whole-house option available in the last 2 years from several of the large HVAC manufacturers. These systems use a mix of technologies ranging from EACs and standard disposable elements to UV lights for germicidal effects and coatings for catalytic conversion of ozone.

All filters or cleaners installed on a central HVAC system are dependent on airflow for effectiveness. It is recommended that the system's fan remain on for maximum benefit. This can lead to increased demand and failure of the blower motor if the units are not maintained on a regular schedule.

ROOM AIR CLEANERS

Portable room air cleaners are very popular and, in some cases, controversial air-filtering devices capable of being moved from room to room. This portability is viewed as an important advantage when focusing on recommended "source control strategies" of indoor air-quality improvement strategies.

Portable room air cleaners include:

1. ionizer air cleaners or purifiers;
2. HEPA room air cleaners; and
3. non-HEPA room air cleaners that contain disposable or washable filters.

Several brands of ionizers (air "purifiers") have been heavily marketed in recent years. Like the EACs, these appliances remove particles from the air by means of an electronic field, reversing the particle's charge and allowing it to collect on a metal plate. Disadvantages associated with these devices include that particles charged by the ionizer and not adherent to the plates remain airborne and exacerbate symptoms. Ionization can also produce ozone, although ozone-to-oxygen converters are now added on many of these devices to decrease the potential for additional ozone generation. Ozone exposure and increased risk for asthma symptoms has been established.[13]

ROLE OF AIR FILTRATION IN DISEASE PREVENTION

Although after 30 years of investigation and published reports (Table II)[14-31] the role of air filtration in disease prevention continues to be debated, some studies do show benefit. Nearly all studies have solely evaluated room air cleaners as a single intervention and are of short duration. Studies looking at HEPA filtration of the breathing zone have fared better. Additionally, nonclinical studies evaluating WHF in the reduction of particulates have been positive.

Wood et al[22] found only modest reductions in airborne levels of Fel d 1 in homes with cats with a room HEPA air filter in the bedroom and no clinical benefit over placebo for cat-sensitive allergic patients. Wood,[32] in his review of air filtration devices, reported 2 other studies that failed to show efficacy in subjects with dust mite allergy. A recent investigation found no effect of HEPA filtration on bronchial hyperresponsiveness in children and adolescents allergic to cats and dogs.[31] Van der Heide et al[24] demonstrated significant reductions in bronchial hyperresponsiveness but no differences in symptom scores or medication use in pet-sensitive asthmatic children. Reisman[33] found reductions in asthma/rhinitis symptoms during active HEPA filter use. Two open-label studies of mold-sensitive patients reported reductions in symptoms and medication use.[32] In Wood's air filtration review,[32] many HEPA filtration studies were small, with inadequate blinding, lack of measured airborne allergen concentrations, and varying air-velocity rates related to room size, location, and occupant

TABLE II. Studies of air filtration systems

References	Study design	Size	Duration of exposure (total)	Population	Intervention	Outcomes	Results
Zwemer and Karibo, 1973[14]	RCT crossover	18	2 wk (4 wk)	Asthmatic subjects (6-16 years old)	Bed headboard laminar flow HEPA filter	Asthma symptoms scores	Significantly less uninterrupted sleep, lower overall symptom scores, and lower daytime wheezing scores
Villaveces et al, 1977[15]	RCT crossover	13	2 wk (4 wk)	Asthmatic subjects (7-15 years old)	PRAC HEPA	Asthma symptom scores/PEF	Significantly fewer asthma symptoms, no difference in PEF
Kooistra et al, 1978[16]	RCT crossover	20	4 wk (8 wk)	Hay fever or asthma (15-68 yrs old)	PRAC HEPA filter	Rhinitis and asthma symptoms	No difference in rhinitis, ragweed, or *Alternaria* species concentrations; nocturnal symptoms reduced
Verral et al, 1988[17]	RCT crossover	13	3 wk (12 wk)	Asthmatic subjects with dust mite allergy (7-27 years old)	PRAC HEPA filter	IgE, PEF, asthma symptoms	No difference in symptoms, IgE levels, or PEF; significant decrease in medication use and improved histamine-induced airway responsiveness
Reisman et al, 1990[18]	RCT crossover	29	4 wk (8 wk)	Rhinitis or asthma (16-61 years old)	PRAC HEPA filter	Rhinitis and asthma symptoms	No difference in rhinitis or asthma symptoms
Antonicelli et al, 1991[19]	RCT crossover	9	8 wk (16 wk)	Subjects with mild asthma with rhinitis (10-28 years old)	PRAC HEPA filter	Rhinitis and asthma symptoms, FEV_1, PEF, PD_{20}, floor allergen levels	No difference in rhinitis or asthma symptoms, FEV_1, PEF, PD_{20}, or floor allergens
Warburton et al, 1994[20]	RCT crossover	12	HEPA: 30.3 d Sham: 24.0 d	Asthmatic subjects (19-64 years old)	PRAC HEPA filter	Asthma symptoms/ PEF/bacterial/ allergen/fungal levels	No difference in asthma symptoms, PEF, or dust concentrations
van der Heide et al, 1997[21]	RCT	45	6 mo	Allergic asthmatic subjects (18-45 years old)	PRAC HEPA filter/PRAC HEPA filter and mattress covers	FEV_1, FVC, PEF, serum IgE levels, eosinophils, allergen sensitization, and floor dust	No differences in FEV_1, FVC, PEF, serum IgE levels, eosinophils, skin test results or airway hyperresponsiveness, or floor dust
Wood et al, 1998[22]	RCT	35	3 months	Cat-allergic adults with asthma or allergic rhinitis (18 to 65 yrs old)	PRAC HEPA filter	Rhinitis and asthma symptoms, PEF, RAST, methacholine response	No difference in asthma, rhinitis, PEF, cat RAST or methacholine challenge
Burroughs, 1998[23]	Model technical cross-sectional	—	Multiple several-hour sampling periods	Three residencies in Atlanta	WHF Comparison; medium efficiency micropleat (1 in); High-efficiency (12-in) filter and fiberglass filter low efficiency to no filter	No clinical data	Reduction in particles with enhanced-efficiency filtration compared with low-efficiency filters and medium-efficiency compared with high-efficiency micropleat filter
van der Heide et al, 1999[24]	RCT crossover	22	3 mo (6 mo)	Asthmatic subjects with cat or dog allergy (6-14 years old)	PRAC HEPA filter	Asthma symptoms, FEV_1, PEF, airway responsiveness to histamine	No difference in asthma symptoms, FEV_1, or PEF; airway responsiveness to histamine significantly reduced

(Continued)

TABLE II. *(Continued)*

References	Study design	Size	Duration of exposure (total)	Population	Intervention	Outcomes	Results
Brehler et al, 2003[25]	RCT crossover	44	2 wk (4 wk)	Adults with seasonal allergic rhinitis (18-65 years old)	Fresh air filtration system	Asthma/rhinitis symptoms	Fewer nighttime hay fever symptoms and increase in morning PEFR
Morgan et al, 2004[26]	RCT crossover	937	12 mo (24 mo)	Asthmatic subjects (5-11 years old)	Multifaceted intervention PRAC HEPA/covers/ education and allergen remediation	Asthma symptoms, dust levels	Fewer asthma symptoms and lower dust allergen levels
Morris et al, 2006[27]	Open crossover	14	1 wk (3 wk)	Hay fever (9-48 years old)	Laminar flow HEPA filtration	Allergic symptoms	Reduced nighttime and daytime rhinitis symptom scores
MacIntosh et al, 2008[28]	Model technical	—	6 mo	Multiroom test home	WHF comparison of 4 in-duct air cleaners and 2 portable air-cleaning devices vs no air cleaner	No clinical data	Except for the portable ionic air cleaner, the devices increased particle removal indoors over baseline values
Myatt et al, 2008[29]	Model analysis	—	12 mo	Several residential templates	WHF using CONTAM multizone indoor air quality model	No clinical data	Forced air systems with high-efficiency filtration provide best control of asthma triggers
Brauner et al, 2008[30]	RCT crossover	21	48 h (96 h)	Nonsmoking couples aged 60-75 years	PRAC HEPA filtered vs nonfiltered air	Microvascular function score	Reduced particle exposure improved microvascular function score
Sulser et al, 2009[31]	RCT	36	12 mon	Asthmatic subjects (6-17 years old)	PRAC HEPA	PFT, cold-air challenge, dust symptoms	No change in FEV_1 after cold-air challenge or medication use or serum ECP levels; trend toward improved bronchial hyperresponsiveness

RCT, Randomized controlled trial; *PRAC*, Portable room air cleaners; *PEF*, peak expiratory flow; FVC, forced vital capacity; *PEFR*, peak expiratory flow rate; *PFT*, pulmonary function test; *ECP*, eosinophil cationic protein.

behaviors. Wood concluded that HEPA room air cleaners might be beneficial for animal allergy in homes in which compliance for pet removal is lacking because the particulates carrying these allergens can remain airborne long enough to permit filtration and removal. A review of 10 randomized controlled trials by McDonald et al,[34] reported that HEPA air filtration was associated with symptom reduction. However, caution was suggested by methodological flaws in most of the studies. A 2-year controlled study[26] of 937 inner-city atopic asthmatic children demonstrated reductions in asthma symptoms and bedroom dust mite and cockroach allergen levels in the environmental intervention group, which included bedroom HEPA filters. Three studies of laminar flow HEPA filtration of the "breathing zone" have shown benefit. Morris et al[27] found significant reductions in allergic rhinitis symptoms in ragweed-sensitive children and adults. Two pediatric asthma studies[14,17] demonstrated significant reductions in medication requirements. Brehler et al[25] reported improvement in seasonal allergic rhinitis symptoms with air filtration through a wall-mounted filter. Recent investigations suggest that HEPA air filtration reduces mold levels in hospital clinical units[35] and reduces fine PM (diameter, $<2.5\ \mu m$) exposure during forest fires and residential wood burning.[36] A recent indoor air quality–modeling system analysis found forced air systems with non-HEPA high-efficiency filtration were the most promising in controlling exposure to environmental tobacco smoke, mold, and cat allergens.[29] Burroughs[23] demonstrated that substantive reductions in fine particulates were attained in ambient space with the use of enhanced efficiency WHF. Recently, Macintosh et al[28] also found WHF to be effective in removing fine particles from indoor air.

FUTURE INVESTIGATION

Future investigations of the efficacy of air cleaning related to disease prevention need to be more rigorous to be conclusive. Symptom severity, medication use, and objective findings (eg, lung function) should be established at baseline. Studies should be of sufficient duration (ie, at least 1-2 years) to have a chance to demonstrate efficacy. Consideration should be given to factors that influence allergen and particulate load along with sampling

location, duration, and timing in relation to activities surrounding the sampling, including cleaning practices. If feasible, the studies should be double blind and placebo controlled.

CONCLUSIONS

The principal role of air cleaning and filtration in the living environment for those with allergic respiratory diseases might relate more toward the reduction of disease progression rather than a "treatment." It is not logical to expect that the observed disease state symptoms, often the result of previous prolonged exposures either in the home, other environments, or both, will abate within a few weeks or even months after the placement of an air-cleaning device or filter in the home environment. Other factors, especially source control and ventilation, might play a more important role than attempts to clean the air after the fact by means of filtration. However, based on our review of the literature, there is sufficient evidence that air filtration does reduce indoor levels of ambient particulates that might trigger disease processes themselves.

As far as optimal choice of cleaning devices, initial cost and ease of regular maintenance should be considered. Portable room air cleaners with HEPA filters, especially those that filter the breathing zone during sleep, appear to be beneficial. For the millions of households with forced air HVAC systems, regular maintenance schedules and the use of high-efficiency disposable filters appear to be the best choices. However, further studies and research in this area are desirable to make more definitive recommendations in the role of air filtration on improving disease outcomes.

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